Influence of Innovative Techniques on Midterm Results in Patients with Minimally Invasive Direct Coronary Artery Bypass and Off-Pump Coronary Artery Bypass

(#2003-11999 . . . September 29, 2003)

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ABSTRACT

Background: There is a paucity of midterm results comparing the efficacy of minimally invasive direct coronary artery bypass (MIDCAB) and off-pump coronary artery bypass (OPCAB) with standard coronary artery bypass grafting (CABG). In addition, the advent of innovative techniques may have improved midterm results for patients who undergo MIDCAB and OPCAB (MID-OPCAB). The purpose of this study was to evaluate the midterm survival results of higher-risk patient groups who have undergone CABG or MID-OPCAB with or without the use of innovative techniques.

Methods: From January 1992 through March 2002, 3670 consecutive patients underwent coronary artery bypass procedures, and their predicted surgical risks were calculated according to the logistic EuroSCORE. The cases of 52 MIDCAB patients and 1796 CABG patients with similar higher-risk EuroSCOREs (11.5 versus 11.4, respectively) who underwent operations from January 1992 to December 1997 were compared (study A). The cases of 89 patients with MID-OPCAB (employing "innovative techniques") and 796 patients with CABG (EuroSCORE, 13.2 versus 13.3, respectively) whose operations took place between 1998 and 2002 were also compared (study B). The National Death Index was used to access mortality data, and Kaplan-Meier curves were constructed for each group of patients. Numbers of arterial grafts, numbers of anastomoses, major complications, in-hospital lengths of stay (LOS), and 30-day mortality rates were noted.

Results: In study A, there were no significant differences in the 30-day mortality rates (2.5% versus 3.9%), incidences of major complications (11.5% versus 16.6%), and LOS (13 days versus 11.7 days) for the MID-OPCAB and CABG patients, respectively. CABG patients received more arterial grafts (47.1% versus 28.9%; $P = .011$), received more distal anastomoses (3.4 versus 2.7; $P < .001$), and had better survival as estimated by Kaplan-Meier curves (94.5 months versus 82.1 months; $P = .023$). In study B, there were no differences in 30-day mortality rates (3.1% versus 2.3%) and incidences of major complications (10.1% versus 12.7%) for MID-OPCAB and CABG patients, respectively. CABG patients received more arterial grafts (72% versus 57.3%; $P = .004$) and more distal anastomoses (3.5 versus 2.8; $P < .001$). However, LOS was shorter for MID-OPCAB patients (7.2 days versus 9.6 days; $P = .019$), and there was no difference in survival time as estimated by Kaplan-Meier curves (47 months versus 46.4 months; $P = .534$).

Conclusions: The advent of innovative surgery significantly improved LOS and "equalized" the rate of survival to 5 years in higher-risk MID-OPCAB patients, compared with similar-risk CABG patients.

Presented at the Sixth Annual Meeting of the International Society for Minimally Invasive Cardiac Surgery, San Francisco, California, USA, June 19-21, 2003.

Received September 22, 2003; accepted September 29, 2003.

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INTRODUCTION

Coronary artery bypass grafting is one of the most common operations worldwide, and its use is expected to increase [Yacoub 2001]. In an attempt to avoid the deleterious effects of cardiopulmonary bypass, the combination of minimally invasive direct coronary artery bypass (MIDCAB) and off-pump coronary artery bypass (OPCAB) grafting has recently been revived. The application of the technique has increased dramatically since the advent of innovative devices for stabilizing the heart. The safety and efficacy of MIDCAB and OPCAB (MID-OPCAB) has been assessed by several studies [Arom 2000, Mehran 2000, Cleveland 2001, Detter 2002, Al Ruzzeh 2003]. Approximately 20% of coronary artery bypass operations are currently done off pump, and this proportion will grow to approximately 50% [Shennib 2001]. Although a large body of evidence supports the theoretical and practical advantages of OPCAB over conventional coronary artery bypass grafting with cardiopulmonary bypass (CABG), there is a paucity of midterm results assessing the efficacy of OPCAB in higher-risk patients [Rose 2003].

The aim of this retrospective study was to evaluate the midterm survival results of patient groups subjected to CABG or MID-OPCAB (with similarly high predicted surgical risks according to the logistic EuroSCORE) through two time periods, ie, before and after the use of innovative techniques in the MID-OPCAB group of patients.

MATERIALS AND METHODS

Patients

The records of 3670 consecutive patients who underwent coronary artery bypass at St. Luke's/Roosevelt Hospital Center at Columbia University between January 1992 and March 2002 were reviewed retrospectively. Registry databases, medical notes, and charts were studied for preoperative and postoperative patient data. Two hundred forty-six patients underwent operations with the MID-OPCAB technique, and 3424 patients underwent operations using the CABG technique. No specified selection criteria were used to determine which procedure, MID-OPCAB or CABG, that individual patients would receive. The selection was based on the individual surgeon's experience and preference. No randomization was involved in this study.

Risk stratification was performed according to the EuroSCORE (full logistic EuroSCORE model; http://www.euroscore.org), and two groups of higher-risk patients (MID-OPCAB versus CABG) were compared. Study A refers to the study period from 1992 to 1997, and study B refers to the period from 1998 to 2002 (MID-OPCAB performed with innovative techniques). Despite the substantial demographic differences between Europe and North America, EuroSCORE performs very well in the Society of Thoracic Surgeons database, and we recommend it as a simple risk-stratification system for studies on both sides of the Atlantic [Nashef 2002]. We used the logistic EuroSCORE for risk stratification in this study because the logistic model is a better risk predictor, especially in high-risk patients [Michel 2003]. In addition, the results of OPCAB operations in high-risk groups of patients can be predicted by the EuroSCORE [Riha 2002]. After matching was carried out, 1796 CABG patients were compared with 52 MID-OPCAB patients (7 patients or 13.5% underwent MIDCAB) in study A, and 796 CABG patients were compared with 89 OPCAB patients (26 patients or 29.2% underwent MIDCAB) in study B. As new innovative techniques became available in 1998 at our institution in the more recent study period, the proportion of OPCAB procedures increased from 3% between 1992 and 1997 to 36% in 2002.

CABG Operation

CABG was carried out through a full sternotomy incision, with the left, right, or both internal thoracic arteries taken down in the usual fashion. The institution of cardiopulmonary bypass was achieved by cannulating the ascending aorta and the right atrium. Standard bypass management included membrane oxygenators, arterial line filters, a non-pulsatile flow of 2.4 L/min per square meter, and a mean arterial pressure greater than 50 mm Hg. Retrograde cardioplegia of either blood or crystalloid solution was delivered for myocardial protection of the arrested heart.

MIDCAB Operation

A left anterolateral minithoracotomy was performed, and the fourth intercostal space was entered without resecting a rib. Other incisions included hemisternotomy and, for robotically assisted MIDCAB, a lower hemisternotomy for multivessel cases and a limited anterior thoracotomy (4-6 cm) for anastomoses of the isolated left internal thoracic artery to the left anterior descending coronary artery. The left internal thoracic artery was harvested under direct vision with the help of a purpose-designed retractor, and the anastomosis to the left anterior descending coronary artery was performed on the beating heart through the minithoracotomy with a running 7-0 or 8-0 polypropylene suture (Prolene; Ethicon, Somerville, NJ, USA) and the help of a mechanical stabilizer. Recently, innovative techniques, such as mechanical stabilizers (CardioThoracic Systems, Cupertino, CA, USA), low-flow carbon dioxide insufflation (Ethicon Endo-Surgery, Cincinnati, OH, USA), and the robotic arm of the da Vinci Robotic Surgical System (Intuitive Surgical, Mountainview, CA, USA), were used during the MIDCAB operation.

OPCAB Operation

The OPCAB operation was usually carried out through a sternotomy incision with the left, right, or both internal thoracic arteries taken down in the usual fashion. Three deep pericardial traction stitches were placed near the left upper and lower pulmonary veins and to the left of the inferior vena cava, thereby achieving elevation of the apex of the heart. To further assist in providing good presentation of the target arteries on the lateral and inferior aspect of the heart, surgeons placed patients in a gentle decubitus Trendelenburg position. Various techniques, such as silicone elastomer (Silastic; Dow Corning, Midland, MI, USA) string snares and intracoronary occluders, suction caps, continuous warm saline irrigation, b blockage or adenosine to slow the heart rate, and fine suction were used during the first study period. Used during the years 1998 to 2002 were stabilization innovations such as the Octopus (Medtronic, Minneapolis, MN, USA) [Spooner 1998, Hart 2000] and others (CardioThoracic Systems, Cupertino, CA, USA), silicone elastomer vessel loops (Quest Medical, Allen, TX, USA), a Medtronic DLP carbon dioxide blower (Medtronic, Grand Rapids, MI, USA), and intraluminal coronary shunts (Bio-Vascular, St. Paul, MN, USA). The innovative techniques have proven to be safe procedures with widening applicability.

Data Analysis

Midterm patient survival data were obtained from the US Social Security Death Index database (http://ssdi.genealogy.rootsweb.com), which was queried in September 2002. These data correspond to minimum and maximum follow-up times of 7 months (March 2002 patients) and 123 months (January 1992 patients), respectively. The database was then updated with the exact date of death for each deceased patient. The

Table 1. Preoperative Characteristics of Higher-Risk Patients with CABG and MID-OPCAB (Study A, 1992-1997)*

Variable	CABG (n = 1796)	MID-OPCAB (n = 52)	P
EuroSCORE	11.4 ± 0.3	11.5 ± 1.8	.949
Age, y	65.1 ± 10.2	64.9 ± 9.6	.900
Female sex, n (%)	618 (34.4)	9 (17.3)	.011
1-Vessel disease, n (%)	117 (6.5)	9 (17.3)	.007
2-Vessel disease, n (%)	404 (22.5)	8 (15.4)	.309
3-Vessel disease, n (%)	1275 (71)	35 (67.3)	.564
Unstable angina, n (%)	1431 (79.7)	32 (61.5)	.001
Previous MI, n (%)	1123 (62.5)	22 (42.3)	.003
Transmural MI (most recent), n (%)	631 (35.1)	12 (23.1)	.077
Previous cardiac operation, n (%)	141 (7.9)	1 (1.9)	.179
Previous PCI, n (%)	187 (10.4)	10 (19.2)	.063
Emergency, n (%)	120 (6.7)	3 (5.8)	.999
Ejection fraction, %	41.8 ± 14	46.9 ± 16.9	.009
Current CHF, n (%)	253 (14.1)	6 (11.5)	.839
PVD, n (%)	365 (20.3)	12 (23.1)	.602
Body mass index, kg/m^2	20.4 ± 4.1	19.8 ± 3.7	.274
Hypertension, n (%)	1279 (71.2)	34 (65.4)	.361
COPD, n (%)	315 (17.5)	14 (26.9)	.096
Diabetes mellitus, n (%)	609 (33.9)	21 (40.1)	.331
Calcified aorta, n (%)	170 (9.5)	3 (5.8)	.475
Renal failure, n (%)	49 (2.7)	3 (5.8)	.178
Smoking in previous year, n (%)	343 (19.1)	5 (9.6)	.104

*Data are presented as the mean ± SD where appropriate. CABG indicates standard coronary artery bypass grafting with cardiopulmonary bypass; MID-OPCAB, minimally invasive direct coronary artery bypass and off-pump coronary artery bypass; MI, myocardial infarction; PCI, percutaneous coronary intervention; CHF, congestive heart failure; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease.

Table 2. Clinical Outcomes, Types of Grafts, Numbers of Anastomoses, and Postoperative Complications for the CABG and MID-OPCAB Patients (Study A, 1992-1997)*

Variable	CABG (n = 1796)	MID-OPCAB (n = 52)	P
EuroSCORE	11.4 ± 0.3	11.5 ± 1.8	.949
30-Day mortality, n (%)	44 (2.5)	2 (3.9)	.374
In-hospital deaths, n (%)	48 (2.7)	3 (5.8)	.171
Length of stay, d	11.7 ± 13.7	13 ± 11.1	.489
BITA, n (%)	826 (46)	14 (26.9)	.007
≥2 Arterial grafts, n (%)	845 (47.1)	15 (28.9)	.011
Anastomoses, n	3.4 ± 1	2.7 ± 1.2	<.001
No complications, n (%)	1498 (83.4)	46 (88.5)	.447
Complications, n (%)	298 (16.6)	6 (11.5)	.447
Intraoperative stroke, n (%)	58 (3.3)	0 (0)	.408
Stroke >24 h, n (%)	6 (0.3)	0 (0)	.999
New Q waves, n (%)	15 (0.8)	2 (3.9)	.081
Deep sternal wound infection, n (%)	14 (0.8)	2 (3.9)	.072
Bleeding/reoperation, n (%)	28 (1.6)	0 (0)	.999
Sepsis/endocarditis, n (%)	17 (1)	1 (1.9)	.403
GI bleeding, perforation, or infarction, n (%)	27 (1.5)	0 (0)	.999
Renal failure/dialysis, n (%)	9 (0.5)	0 (0)	.999
Respiratory failure, n (%)	92 (5.1)	2 (3.9)	.999

*Data are presented as the mean ± SD where appropriate. CABG indicates standard coronary artery bypass grafting with cardiopulmonary bypass; MID-OPCAB, minimally invasive direct coronary artery bypass and off-pump coronary artery bypass; BITA, bilateral internal thoracic arteries; GI, gastrointestinal.

120-month Kaplan-Meier survival plots were determined and compared for the patients who underwent operations between 1992 and 1997, and 48-month Kaplan-Meier survival plots were compared for the patients who underwent operations between 1998 and 2002.

Statistical Methods

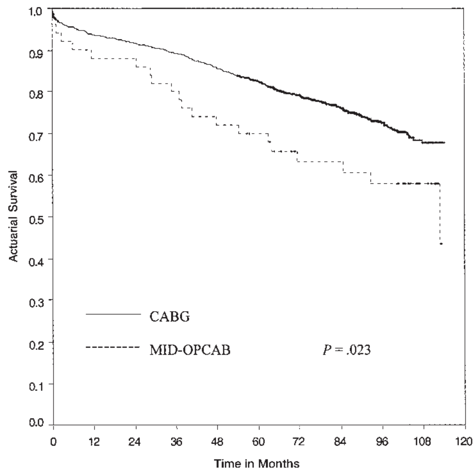
Numerical variables are presented as the mean ± SD for both patient groups. The data were evaluated with the independent Student *t* test or the Mann-Whitney *U* test where appropriate. Patient characteristics and postoperative complications were compared with the Fisher exact test or the χ^2 test where appropriate. The Kaplan-Meier survival curves were compared with the log-rank test. *P* values of less than .05 as determined with SPSS 11.0 Software (SPSS, Chicago, IL, USA) were considered statistically significant.

RESULTS

In study A, higher-risk patients who underwent MID-OPCAB were compared with patients with similar average EuroSCOREs who underwent CABG (11.5 versus 11.4, respectively; $P = .949$). The preoperative characteristics of the two groups (Table 1) ensured that the two groups were appropriately matched in 17 of 22 characteristics. MID-OPCAB patients were less likely to be women, and the two groups differed in the incidences of single-vessel disease (MID-OPCAB, 17.3%; CABG, 6.5%; $P = .007$), unstable angina (MID-OPCAB, 61.5%; CABG, 79.7%; $P = .001$), and previous myocardial infarction (MID-OPCAB, 42.3%; CABG, 62.5%; $P = .003$). As a group, the MID-OPCAB patients had better ejection fractions than the CABG patients (46.9% versus 41.8%; $P = .009$).

Table 2 compares clinical outcomes, the types of grafts, the number of anastomoses performed, and postoperative complications. There were no significant differences between the two groups in 30-day mortality, in-hospital mortality, length of stay, complications, and 12 other characteristics of the 18 evaluated. CABG patients received more bilateral internal thoracic arteries (46% versus 26.9%; $P = .007$), more arterial grafts (2 or more arterial grafts, 47.1% versus 28.9%; $P = .011$), and more distal anastomoses (anastomoses per patient, 3.4 versus 2.7; $P < .001$). Long-term survival rates as estimated by Kaplan-Meier curves were in favor of the CABG group (Figure 1), and this difference was statistically significant ($P = .023$, log-rank test).

In study B, higher-risk MID-OPCAB patients were compared with a group of CABG patients with a similar average EuroSCORE (13.2 versus 13.3, respectively; $P = .946$). The preoperative characteristics of the two groups are shown in Table 3. The two groups differed in the incidences of unstable



Patients at Risk

	Months									
	0	12	24	36	48	60	72	84	96	108
CABG	1796	1583	1551	1509	1451	1289	967	683	350	97
MID-OPCAB	52	44	44	40	36	33	25	25	23	10

Figure 1. Kaplan-Meier estimates of survival in higher-risk patients (study A). CABG indicates coronary artery bypass grafting with cardiopulmonary bypass; MID-OPCAB, minimally invasive direct coronary artery bypass and off-pump coronary artery bypass.

Table 3. Preoperative Characteristics of Higher-Risk Patients with CABG and MID-OPCAB (Study B, 1998-2002)*

Variable	CABG (n = 796)	MID-OPCAB (n = 89)	*P*
EuroSCORE	13.3 ± 0.4	13.2 ± 1.5	.946
Age, y	67.3 ± 9.8	68.4 ± 10.6	.305
Female, n (%)	278 (34.9)	35 (39.3)	.410
1-Vessel disease, n (%)	22 (2.8)	4 (4.5)	.322
2-Vessel disease, n (%)	109 (13.7)	16 (17.8)	.271
3-Vessel disease, n (%)	665 (83.5)	69 (77.5)	.153
Unstable angina, n (%)	567 (71.2)	48 (53.9)	.001
Previous MI, n (%)	269 (33.8)	10 (11.2)	<.001
Transmural MI (most recent), n (%)	347 (43.6)	29 (32.6)	.046
Previous cardiac operation, n (%)	57 (7.2)	6 (6.7)	.999
Previous PCI, n (%)	122 (15.3)	21 (23.6)	.044
Emergency, n (%)	112 (14.1)	2 (2.3)	.001
Ejection fraction, %	40.4 ± 15.3	47.1 ± 13.7	<.001
Current CHF, n (%)	190 (23.9)	14 (15.7)	.086
PVD, n (%)	212 (26.6)	35 (39.3)	.011
Body mass index, kg/m^2	20.8 ± 4.6	21.4 ± 4.6	.202
Hypertension, n (%)	632 (79.4)	67 (75.3)	.366
COPD, n (%)	93 (11.7)	11 (12.4)	.862
Diabetes mellitus, n (%)	347 (43.6)	28 (31.5)	.028
Calcified aorta, n (%)	71 (8.9)	16 (18)	.006
Renal failure, n (%)	24 (3)	0 (0)	.160
Smoking in previous year, n (%)	81 (10.2)	8 (9)	.853

*Data are presented as the mean ± SD where appropriate. Abbreviations are expanded in the footnote to Table 1.

angina (MID-OPCAB, 53.9%; CABG, 71.2%; *P* = .001), previous myocardial infarction (MID-OPCAB, 11.2%; CABG, 33.8%; *P* < .001), peripheral vascular disease (MID-OPCAB, 39.3%; CABG, 26.6%; *P* = .011), diabetes mellitus (MID-OPCAB, 31.5%; CABG, 43.6%; *P* = .028), and calcification of the aorta (MID-OPCAB, 18%; CABG, 8.9%; *P* = .006). The MID-OPCAB patient group had a better average ejection fraction (47.1% versus 40.4%; *P* < .001), more previous percutaneous coronary interventions (23.6% versus 15.3%; *P* = .044), and fewer emergent operations (2.3% versus 14.1%; *P* < .001). The CABG patients were of "worse" prognosis for 6 of the characteristics, the MID-OPCAB patients were of "worse" prognosis for 3 characteristics, and the two groups were appropriately matched for 13 characteristics.

Table 4 compares clinical outcomes, types of grafts, number of anastomoses performed, and postoperative complications. There were no significant differences in 30-day or in-hospital mortality rates or in the numbers and various types of complications. The MID-OPCAB group had a shorter average length of stay than the CABG group (7.2 days versus 9.6 days; *P* = .019), but CABG patients received more arterial grafts (2 or more arterial grafts, 72% versus 57.3%; *P* = .004) and more distal anastomoses (anastomoses per patient, 3.5 versus 2.8; *P* < .001). The two groups were similar in 15 characteristics. There was no difference between the two groups in midterm survival rate estimated by Kaplan-Meier curves (Figure 2).

DISCUSSION

Coronary artery bypass on the beating heart without cardiopulmonary bypass was reintroduced in the early 1990s. Since then, numerous reports have demonstrated the superior safety and efficacy of OPCAB and MIDCAB techniques over those of CABG patients in various risk groups [Puskas 1999, 2001, Detter 2002, Magee 2002]. Although various investigators have presented excellent mortality rates, concern has been raised concerning the long-term and midterm survival rates [Abu-Omar 2002]. The present study evaluates the midterm survival results of higher-risk patients with MID-OPCAB after the advent of innovative techniques in an attempt to determine the beneficial effects of these innovations in the field of beating heart surgery.

This retrospective comparative study shows that the use of the MID-OPCAB procedure after the introduction of innovative techniques significantly reduced the length of stay and equalized the rates of survival to 5 years compared with CABG patients at similarly high risk (even though the MID-OPCAB group received a significantly lower proportion of arterial grafts and a lower total number of anastomoses). Even when we perform the statistical analysis for the highest-risk patients (EuroSCORE >14), we get similar midterm survival results before and after the use of innovative techniques. During the period from 1992 to 1997 (EuroSCORE of 30.4 for the MID-OPCAB group [n = 34] versus EuroSCORE of 29.4 for the CABG group [n = 575]; *P* = .743), the long-term survival rate as estimated by Kaplan-Meier curves was in favor of the CABG group (*P* = .0001, log-rank test; data not shown), whereas during the period from 1998 to 2002 after the introduction of innovative techniques (EuroSCORE of 35.7 for the MID-OPCAB group [n = 85] versus EuroSCORE

Table 4. Clinical Outcomes, Types of Grafts, Numbers of Anastomoses, and Postoperative Complications for the CABG and MID-OPCAB Patients (Study B, 1998-2002)*

Variable	CABG (n = 796)	MID-OPCAB (n = 89)	P
EuroSCORE	13.3 ± 0.4	13.2 ± 1.5	.946
30-Day mortality, n (%)	25 (3.1)	2 (2.3)	.999
In-hospital deaths, n (%)	27 (3.4)	2 (2.3)	.760
Length of stay, d	9.6 ± 9.3	7.2 ± 5.8	.019
BITA, n (%)	321 (40.3)	34 (38.2)	.698
≥2 Arterial grafts, n (%)	573 (72)	51 (57.3)	.004
Anastomoses, n	3.5 ± 1	2.8 ± 1.1	<.001
No complications, n (%)	695 (87.3)	80 (89.9)	.611
Total complications, n (%)	101 (12.7)	9 (10.1)	.611
Intraoperative stroke, n (%)	14 (1.8)	1 (1.1)	.999
Stroke >24 h, n (%)	14 (1.8)	0 (0)	.383
New Q waves, n (%)	1 (0.1)	1 (1.1)	.191
Deep sternal wound infection, n (%)	17 (2.1)	2 (2.3)	.999
Bleeding/reoperation, n (%)	17 (2.1)	2 (2.3)	.999
Sepsis/endocarditis, n (%)	10 (1.3)	1 (1.1)	.999
GI bleeding, perforation, or infarction, n (%)	12 (1.5)	1 (1.1)	.999
Renal failure/dialysis, n (%)	11 (1.4)	1 (1.1)	.999
Respiratory failure, n (%)	52 (6.5)	4 (4.5)	.645

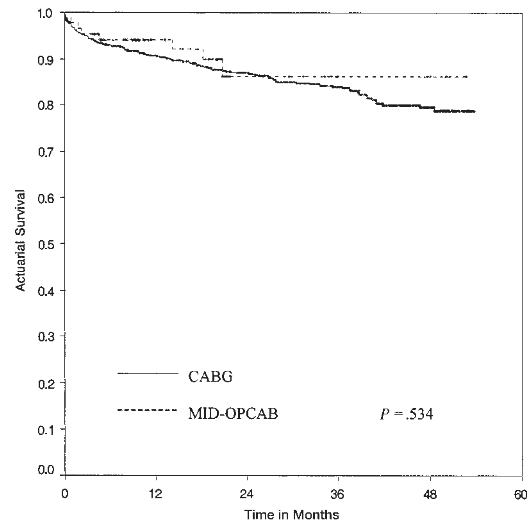
*Data are presented as the mean ± SD where appropriate. Abbreviations are expanded in the footnote to Table 2.

of 29.5 for the CABG group [n = 184]; *P* = .004), there was no difference in midterm survival results between the MID-OPCAB and CABG groups as estimated by Kaplan-Meier curves (*P* = .112, log-rank test; Figure 3).

The preoperative EuroSCORE surgical risks of approximately 11 in study A and 13 in study B and the comparable high rates of 3-vessel disease in the MID-OPCAB and CABG groups suggest that the MID-OPCAB technique can be used with all higher-risk cardiac surgical patients with satisfactory clinical and midterm survival results. The disadvantages of cardiopulmonary bypass and accompanying cardioplegic arrest, including possible myocardial injury [Ascione 1999], systemic inflammatory responses that can contribute to multiorgan damage, and the greater need for blood transfusion [Haase 2003], have been extensively described. The avoidance of these harmful effects may be the reason behind the protective effects of OPCAB, and OPCAB may consequently offer a better outcome for higher-risk patients [Baumgartner 1999, Yokoyama 2000].

The overall 30-day, in-hospital, and midterm mortality rates for the two groups in study B confirm that MID-OPCAB can be carried out with the same mortality rates as CABG, and this result reflects the safety and efficacy of the MID-OPCAB procedure. The observed 30-day mortality rate (2.3%) in this series of higher-risk patients was markedly lower than the predicted risk of 13.2%. This finding suggests that higher-risk patients benefit from the MID-OPCAB operation.

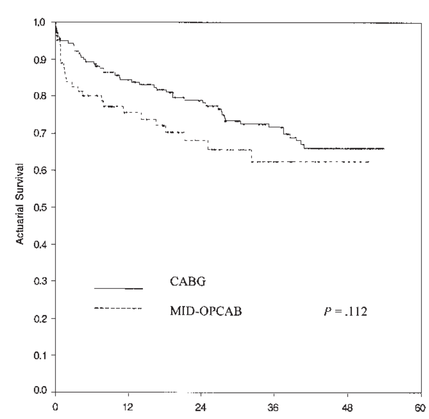
The limitation of this study is that it is a nonrandomized retrospective review with a small number of patients in the MID-OPCAB group. It compares the preoperative and postoperative characteristics of MID-OPCAB and CABG groups of patients at largely similar higher risks and with the same average logistic EuroSCOREs. The OPCAB or CABG surgical procedure used in each case was largely influenced by the surgeon's preference. In this study, we had no follow-up data assessing the reinterventions after the operation, which is a



Patients at Risk

	Months 0	12	24	36	48
CABG	796	592	461	302	116
MID-OPCAB	89	50	14	6	4

Figure 2. Kaplan-Meier estimates of survival in higher-risk patients (study B). CABG indicates coronary artery bypass grafting with cardiopulmonary bypass; MID-OPCAB, minimally invasive direct coronary artery bypass and off-pump coronary artery bypass.



Patients at Risk

	Months 0	12	24	36	48
CABG	184	132	105	81	43
MID-OPCAB	85	45	29	12	1

Figure 3. Kaplan-Meier estimates of survival in highest-risk patients (EuroSCORE >14) from 1998 to 2002. CABG indicates standard coronary artery bypass grafting with cardiopulmonary bypass; MID-OPCAB, minimally invasive direct coronary artery bypass and off-pump coronary artery bypass.

valuable parameter for evaluating long-term outcomes. In the study of Gundry et al, OPCAB provided long-term results comparable with those of CABG after a 7-year follow-up, but there was a 3-fold increase in reinterventions in the OPCAB group [Gundry 1998]. However, this study was conducted at a time when innovative techniques for performing OPCAB were not available. Another limitation of our study is that we examined all-cause mortality and were unable to determine the causes of death (cardiac or noncardiac).

The currently available randomized studies comparing OPCAB with CABG involve only relatively low–risk patients [van Dijk 2001, Angelini 2002, Nathoe 2003]. In our database, no deaths were observed from 1998 to 2002 in low-risk patients (EuroSCORE <2), and a comparison of OPCAB and CABG patients for the period from 1992 to 1997 (an approximately 90% 10-year actuarial survival rate) showed no differences (data not shown). It would be ideal to have a prospective randomized trial design for high-risk patients and a substantially larger cohort of surgical patients restricted only to surgeons who are adequately experienced in both techniques.

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